CalCOFI and Academia

presented by

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Introduction

I offer my perspective, as an academician, on the future of CalCOFI. I do so after conversations with colleagues within, and outside, Scripps, including Farooq Azam, Patricio Bernal, George Boehlert, Teri Chereskin, Ralf Goericke, Tom Hayward, Greg Mitchell, and Elizabeth Venrick. However, the views expressed here should be taken as my personal views.

I begin by offering my conclusions, each prefaced by an observation. First, CalCOFI is arguably the finest oceanographic time series in the world. The challenge is how to ensure continuity of the CalCOFI times series in the next fifty years. Second, CalCOFI could do better, in perception and in reality. The challenge is how to enhance CalCOFI. My answer: innovate. The two words to remember are continuity and innovation.

Historical Perspective

Hewitt (CalCOFI Rep. 29:27-41, 1988) describes the beginning of CalCOFI. The Marine Research Committee, the precursor of CalCOFI, was created in 1949 to investigate the causes of the decline of the Pacific sardine (*Sardinops sagax*) off California. The present CalCOFI Committee was created in 1957. In 1949, the sardine catch had fallen to less than one quarter of its peak and the northern anchovy (*Engraulis mordax*) catch was minimal. The objective of CalCOFI, from its genesis, was to understand, using observations at sea, the physics, chemistry, and biology of the ecosystem of which Pacific sardine is a part. In the ensuing years, the catch of Pacific sardine continued to decline and, eventually, a moratorium on its capture was instituted. Recently, the sardine has returned and fishing begun. The northern anchovy catch was maximal when sardine was not fished and, in recent years, has declined in abundance, although not to prior levels. In general, the populations of sardine and anchovy off California continue to wax and wane, with no clear understanding of the cause. The original mission of CalCOFI remains.

The initial partners, in 1949, included the U.S. Bureau of Commercial Fisheries (now NOAA), the California Department of Fish and Game (CDF&G), Scripps Institution of Oceanography (SIO), and the California Academy of Science. The latter was dropped in 1957. The current CalCOFI Committee has one member from each of NOAA, CDF&G, and SIO. The Committee advises its respective organizations on participation in and coordinates the quarterly CalCOFI cruises, annual meeting, and publications, including CalCOFI Reports, Data Reports, and Atlases.

CalCOFI is unique in comparison with other organizations responsible for oceanographic time series. This is due, in part, to its combination of basic and applied disciplines, including oceanographers, fisheries scientists, managers, and enforcers.

The station plan and sampling frequency has diminished significantly from 1950 to the present, with some gaps in sampling. The core observations on station are at present:

- Hydrography: temperature and salinity with depth (pressure)
- Chemistry: dissolved oxygen and nutrients (N, P, Si)
- Biology: chlorophyll a (discrete [*in vitro*] and profiled [*in vivo*]), primary productivity, species of fish eggs and larvae (CalVET and bongo net collections), and zooplankton (bongo net collection, displacement volume).

Underway observations include:

- CUDLS (Continuous Underway Data Logger System; temperature, salinity, and chl *a* fluorescence)
- ADCP (Acoustic Doppler Current Profiler; currents and zooplankton backscatter)
- Simrad EK-500 echo sounder (fish abundance)
- CUFES (Continuous Underway Fish Egg Sampler; species of fish eggs)
- Visual observations of marine birds and mammals

Additional observations in recent years include:

- Bio-optics: on station, vertical profiles of optical properties, potentially useful for estimation of primary productivity
- Phytoplankton pigment analysis in particulate matter and plankton collected on station
- Optical Plankton Counter deployment on station in bongo net, to assess vertical and size distribution of the zooplankton.

The accomplishments of CalCOFI are numerous. From the academic perspective, these are perhaps best manifest in the numerous, peer-reviewed papers by PhD students, postgraduate researchers, and research scientists having participated in or used the data of CalCOFI.

This historical perspective on CalCOFI leads one to recognize the need for continuity, particularly in regard to quarterly cruises, the present, minimal spatial coverage, and the core measurements. In addition, there is a real need for continuity of funding.

The Future

I suggest six areas in which change within CalCOFI might occur. The names used are arbitrary. More important are the concepts.

Mission Statement - The original mission of CalCOFI, to understand the population dynamics of the Pacific sardine in the context of its associated ecosystem, remains. However, in doing so over the past 50 years, CalCOFI has become a cardinal time series in oceanography, germane to documenting and understanding long-term change in the ocean and climate. Thus, it may be appropriate to restate the mission of CalCOFI to reflect this duality. Interestingly, both bear on the economy of California.

The value of CalCOFI in the context of long-term change is apparent in the global mean surface air temperature (GMSAT) measured from 1850 to present and predicted by the IPCC, (Intergovernmental Panel on Climate Change) to 2050. Between 1850 and 1950, GMSAT increased ca. 0.2 ºC. In the first 50 years of CalCOFI (1950-2000), GMSAT increased ca. 0.6 ºC. In the next 50 years, GMSAT is predicted to increase a further 1.5 ºC. Uncertainty exists for these predictions and the concurrent ocean changes. CalCOFI core measurements over the next 50 years will be invaluable in documenting and understanding long-term change. Should this be explicit within the mission of CalCOFI?

Science Board – Good advisors can infuse new ideas into an organization. To this end, I suggest the creation of a Science Board to advise the CalCOFI Committee. Such a board might consist of three distinguished scientists, with expertise relevant to the mission of CalCOFI, and three members of CalCOFI. It might be charged with a biannual discussion of CalCOFI and, in particular, opportunities for innovation whilst mindful of the mission.

Focus Periods – It has been suggested that CalCOFI might consist of two parts. First, the 'backbone' of core measurements to maintain the time series. Second, periods, e.g. of five years nominal duration, of focused research. Possible foci include technology development, the region of isopycnal shoaling and sardine spawning, and the microbial food web. Such a focus might enhance the organization and funding of innovative research in CalCOFI.

Postdoctoral Fellowships – Postgraduate researchers are an excellent stimulus for a science organization. They bring the most recent ideas and skills and thus stimulate innovation. They are able to focus nearly all their efforts on research. They can work jointly with SIO, NOAA, and CDF&G on matters ranging from basic to applied. They carry knowledge of CalCOFI when they leave. Creation of permanent CalCOFI postdoctoral fellowships should be considered. Postdoctoral funds should be routinely written into grants for ancillary research. Pre-doctoral scholarships might be considered as well. There is a rich history of graduate student participation in CalCOFI which must be continued.

Institutional Coordination – The present CalCOFI region lies at the southern end of the California Current. It is influenced by advection from the north and south, by tropical events such as ENSO, and should be viewed in the larger context of the climate and ocean of the North Pacific. To this end, CalCOFI should strive to enhance its coordination with activities to the south (e.g. IMECOCAL), north (e.g. MBARI, Humboldt, Newport, and NEP GLOBEC), and climate research groups (e.g. SIO, PFEL).

Innovation – Innovation will come in ways not now known. It will derive from within CalCOFI, including students, postgraduate researchers and permanent scientists, from advisors such as the proposed Science Board, and from the community at large. It must complement, not displace, the core measurements. Most important is to create an environment that fosters innovation. Several potential areas of innovation are listed below.

Underway, vertical profiling – Two systems, among others, could be considered. The first is the Moving Vessel Profiler of Brooke Ocean. This would provide automated, vertical profiles

between stations of temperature, salinity, and pressure; chlorophyll *a* fluorescence; and particle size and concentration from a Laser Optical Plankton Counter. The second is the underway CTD under development at SIO.

Alternative platforms – Buoys, floats, and gliders are being considered for deployment in the CalCOFI region. Such devices allow semi-continuous measurement of physical, chemical, and biological variables, thereby augmenting the quarterly observations during CalCOFI cruises and enhancing our knowledge of variability in the time, space, and frequency domains. They range from moored, heavily-instrumented buoys to slow-moving, far-reaching, efficiently-instrumented floats and gliders.

Bio-optical estimation of primary productivity – At present, ^{14}C-tracer incubations are used on quarterly cruises to estimate the rate of primary productivity. Efforts are underway to possibly replace experimental measurements with estimates from models using bio-optical measurements.

Pigment analysis – Greater characterization of phytoplankton pigments in particulate matter and plankton is underway and could be expanded. This allows for a greater understanding of the relative occurrence of coccoid, photosynthesizing bacteria and larger phytoplankton, e.g. diatoms and dinoflagellates, and thus food web structure.

Laser Optical Plankton Counter – The OPC currently used in CalCOFI senses particles larger than 250 Fm equivalent spherical diameter (ESD). The new Laser OPC senses particles at least as small as 70 m ESD, encompassing more of the food available to young fish larvae.

Synthesis and Modeling – There remains a great opportunity and real need for efforts to synthesize data and model processes in the CalCOFI region. This could well be the subject of graduate or postgraduate research. Some of this goes on now with exciting results. Our understanding of a system is perhaps best evaluated by our ability to predict it or, in the lexicon of meteorologists, forecast skill. CalCOFI provides an excellent opportunity for such prediction and forecasting.

Conclusion

I conclude by again offering two words which I believe characterize the future of CalCOFI: continuity and innovation. presented by David Checkley (UCSD SIO)